

**INTERNAL RECIRCULATION FOR MAGNETICALLY COUPLED  
POSITIVE DISPLACEMENT PUMPS**

**CROSS REFERENCE TO RELATED APPLICATIONS**

**[0001]** This claims the benefit of U.S. Provisional Patent Application No.

60/429,900 filed November 27, 2002.

**STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR  
DEVELOPMENT**

**[0002]** Not applicable.

**FIELD OF THE INVENTION**

**[0003]** This invention relates to magnetically coupled positive displacement pumps, and in particular to cooling circulation to remove heat due to eddy currents in the magnetic coupling of such pumps.

**BACKGROUND OF THE INVENTION**

**[0004]** Positive displacement rotary pumps include, but are not limited to, gear, lobe, progressive cavity, and vane designs. These pumps all take in liquid on the suction side (low pressure) and deliver a “captive volume” of liquid to the discharge side (high pressure). Typically, these pumps are used to meter, transfer, and/or control the delivery of liquids from their point of origin directly to their point of use. Also, these pumps are applied for the purpose of circulating liquids as in the case of heat exchange, or maintaining a “point of use” supply. With all these pumps, a minor amount of “slip” is inherent to their design.

**[0005]** Slip is defined as the reverse flow of liquid from the pump’s discharge side back to the pump’s suction side along the various mating surfaces between rotating

components and the pump's body. The volumetric efficiency (%) of these pumps is measured as the total actual throughput (gallons per minute, GPM) as a percent of the total theoretical throughput displacement (GPM).

[0006] Typically, the only heat generated as a liquid is passed through the pump, is a result of viscous drag, turbulence, and surface friction between the pump's moving parts and the pump body and pump bearings. Frictional heat is also generated at the rotating, contacting surfaces of the sealing elements of the pump. The total heat rise of a liquid as it passes through a conventionally sealed positive displacement pump is typically low to insignificant.

[0007] The subject positive displacement pumps are provided with either, 1) traditional sealing devices (mechanical, packing, and lip type seals to name a few), or 2) they are provided with a "sealless" magnetic coupling. The present invention relates to magnetically coupled positive displacement pumps.

## DISCUSSION OF THE PRIOR ART

[0008] For the purpose of simplicity, the following figures and discussion focuses on external gear pumps.

[0009] Referring to Figs. 1-3, in typical magnetically coupled external gear pumps, the driven magnet 3 is mounted directly to the pump drive shaft 7 that in turn is connected to the drive gear 4a which is in the pumping chamber 14 along with driven gear 4b. Around the driven magnet, the liquid is sealed in by the containment can 5, and thus the liquid being pumped is completely sealed within the pump. Outboard of the containment can 5 is the drive magnet 6 which in turn is connected to the shaft (not shown) of the motor which rotates the drive magnet 6. Rotating the drive magnet 6

rotates the driven magnet 3 to drive the gear pump 12, since the drive and driven magnets are magnetically coupled to one another and therefore remain "fixed" in relation to one another as they rotate. Thus, a magnetic field passes between these two magnets and therefore rotates with them and through the containment can 5.

[0010] Conventional containment can construction is metallic, and typically is stainless steel or high Nickel alloy steel. Rotation of the magnetic field continuously "through" the metallic containment can creates heat by generating eddy currents. This heat is captured by the liquid trapped inside the containment can and is removed by recirculating fresh liquid from the pump into the containment can. The recirculating liquid is delivered from the pump's high pressure side and returned to the pump's low pressure side. Recirculation through the containment can is a requirement to remove the heat generated by the rotating magnetic field. Without this heat removal, the liquid would vaporize or otherwise degrade with subsequent thermal expansion and severe damage to the can and the coupling magnets would result.

[0011] The ability to provide the desired recirculation of liquid to the containment can is therefore of primary importance for the application of magnetically coupled pumps. The trade-off to a high recirculation rate with increased heat removal is a reduced output flow – low volumetric efficiency. A balance must be made – too little a recirculation rate removes too little heat and can result in the detrimental effects cited above, too great a recirculation rate decreases the volumetric efficiency and therefore lowers the output flow rate (GPM).

[0012] A conventional recirculation design is a path that brings the liquid along a circuitous route along the pump drive shaft 7 and through a groove cut in the ID of the

bearings 9 or through another passageway. The exact location of this flow path and design will vary among manufacturers. Generally, this flow path may be narrow, long, circuitous, and fixed. Therefore, it is critical that this pathway remains open and that the predetermined recirculation rate (inherent to the design of the pump by the manufacturer) is within a range of acceptable limits for the proper performance of magnetically coupled pumps.

[0013] Because of the wide range of application of positive displacement pumps, particularly for the chemical processing industries, there is a need to allow the end user to have the ability to select and/or modify the liquid recirculation rate when a magnetic coupling is used. This capability is not now afforded to the user of a conventional magnetically driven positive displacement pump.

[0014] It should be noted that non-metallic containment can designs are in use today as a means to eliminate the generation of heat. The trade-off in going from a metallic to a non-metallic can is a thicker wall and/or a lower limit on pump discharge pressure. The thicker wall increases the magnet's spacing and thus requires a larger magnet set to overcome the field loss of the greater separation.

## SUMMARY OF THE INVENTION

[0015] The invention provides an improvement to a positive displacement pump driven by a magnetic coupling in which at least one port passageway extends from the interior of the pump housing through to the interior of the containment can. This provides for direct circulation of cooling fluid to the can, and also permits mounting different size orifices in the port passageway so as to adapt the pump to different applications.

[0016] In a preferred form, at least two port passageways extend between the interior of the containment can and the high pressure and low pressure cavities of the pump, with at least one port passageway for each of the high pressure and low pressure ports. Thereby fluid is provided circulating through the can from the high pressure port to the low pressure port of the pump. Either or both of the passageways may be provided with an orifice, and the orifice size is adjustable, for example by the orifice being replaceable with an orifice having a different orifice size, so that the orifice size can be changed to adapt to different conditions or applications. Placing the orifice in the low pressure passageway has benefits when pumping viscous liquids, since the liquid is heated in the can, thereby lowering its viscosity, before it must pass through the orifice. This position of the orifice also has a benefit when pumping liquids with a high vapor pressure or low boiling point since that position maintains the maximum pressure within the containment can.

[0017] These and other objects and advantages of the invention will be apparent from the detailed description and drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Fig. 1 is a longitudinal view with portions broken away showing a pump of the invention;

[0019] Fig. 2 is a cross-sectional view along the plane of the line 2-2 of Fig. 1; and

[0020] Fig. 3 is a cross-sectional view along the plane of the line 3-3 of Fig. 2.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0021] A design of the invention is shown in Figs. 1-3. A gear pump is selected to be shown as a typical positive displacement pump. The conventional fixed recirculation route is replaced by high pressure port passageway 1a and low pressure port passageway 1b (passageway 1b shown out of plane in Fig. 1), which provide communication between the interior of the containment can 5 and the pumping cavity 14, the passageway 1a providing communication on the high pressure side 14a of the pumping cavity 14 and the passageway 1b providing communication on the low pressure side 14b of the pumping cavity 14.

[0022] Each port passageway 1a, 1b opens in the pumping cavity immediately on the pumping cavity 14 side of the pump flange 10. The bearings 9 have typical outside shapes, being cylindrical with a flattened side, with the flattened sides of the two bearings 9 on each side of the pumping gear set facing each other. The outer surfaces of the bearings create a cleft shaped space at the junction of the outer sides of the bearings 9 adjacent the pump flange 10, one such space on the high pressure side and one on the low pressure side of the pump, into which the passageways 1a and 1b open into the pumping cavity 14, as shown in Fig. 2.

[0023] The port passageways 1a, 1b are straight, short passages of relatively large diameter and are threaded to accept an orifice plug 2, which has a small hole to allow fluid to pass at a controlled rate through the ports 1a, 1b. The orifice plug 2 has a means of wrench attachment so that it can be easily installed and removed. This can take a number of forms such as a female hex socket or screw driver slot. It is recognized that some fluid continues to travel from the pump to the can by way of the normal shaft to

bearing running clearance. However, this flow rate is quite low. The invention significantly augments this flow path.

[0024] In the illustrated embodiment, an orifice plug 2 is provided in the low pressure port passageway 1b only. The high pressure port passageway 1a is left open. Both port passageways are threaded to allow an orifice plug 2 to be located on either side, both sides, not at all, or to allow the use of two orifice plugs, depending on the desire of the user. Also, the orifice plug(s) may be placed on either the magnet side or the pumping side of the pump flange 10. Regardless of the direction of flow of the pump, only one orifice plug is required to restrict flow to a predetermined rate, and it may be mounted on either the high pressure or low pressure side. To meet even more demanding requirements for recirculation, the recirculation port passageways 1a, 1b could be made to accommodate a larger flow by exchanging the orifice plug 2 with one with a bigger hole, or to cause a smaller flow by using an orifice plug with a smaller hole. In extreme cases, the port itself could be drilled to a larger diameter. Alternatively, the orifice could be provided by an adjustable valve, such as a needle valve. In any event, whether by replacing the orifice, by drilling out the orifice or adjusting the orifice opening of a valve, the orifice size is adjustable.

[0025] By allowing the end user to easily change the orifice plug 2 to a larger or smaller orifice, or to change its location, the heat removal rate may be changed at a slight sacrifice or gain in volumetric efficiency. Similarly, the volumetric efficiency may be improved by decreasing the heat removal rate when heat removal is not as critical.

[0026] With the added flexibility of an orifice plug design recirculation loop, positive displacement pumps with magnetic couplings find a much broader application base.

[0027] Liquids with high vapor pressures and/or low boiling points such as solvents, would typically require a higher recirculation rate to limit the maximum temperature rise of the liquid. For these fluids, the orifice plug would be best situated on the return side of the recirculation loop (the suction side of the pump) to maintain maximum pressure within the containment can. Viscous liquids are often limited from use with magnetic couplings because of the inability to move a sufficient volume of a viscous liquid through the containment can to remove heat. Viscous liquids require a high pressure drop to pass through long, small diameter, circuitous pathways. This present design allows a substantially greater diameter and shorter length pathway, both of which aid in the ability to pass a viscous liquid through the recirculating loop. For viscous liquids, the orifice plug would be either removed entirely or would be placed on the return side of the recirculation loop (the suction side of the pump). Improving the situation, the viscosity of the liquid would typically be decreased because of its increased temperature having moved through the containment can. Therefore, the lower viscosity (warmer) liquid more easily passes through a given diameter orifice (lower pressure drop).

[0028] Another application benefit is for pumps in systems with a low discharge pressure. It is the differential pressure across the pump 12 that is the motive force to move the liquid through the recirculation loop. With little differential pressure, there is little flow and conventional magnetically driven positive displacement pumps lose their



ability to sufficiently remove heat from the containment can. With the present invention, the orifice diameter is increased to promote greater flow and to accommodate this situation.

[0029] Another benefit is for pumps in systems with a low available NPSH (net positive suction head). The liquid that is provided to the pump's inlet with a low NPSH is close to its point of vaporization once inside the suction chamber. This is the area to which the heated recirculation liquid is returned, thus pushing the suction side temperature even closer to the point where cavitation would occur (cavitation is the unwanted expansion of liquid to gas which results in physical damage (typically pitting) to all suction side wetted surfaces). A greater recirculation rate will provide a lower temperature for the recirculating liquid as it returns to the suction chamber.

[0030] The orifice plug recirculation loop of the invention allows the liquid to be easily pressurized into the containment can area from the high pressure side of the pump and returned via the return port to the suction side of the pump. As the main body of liquid passes through the pump, a small fraction of liquid is directed to recirculation for the purpose of removing heat generated by passing the magnetic field through the containment can. Sufficient heat removal is of paramount importance for the protection of the pump, in particular the magnetic coupling and the containment can, and for protecting the liquid itself from heat degradation, vaporization, or crystallization.

[0031] The invention provides the ability to the end user to incorporate the proper sized orifice in the recirculating loop to balance the trade-off between heat removal and volumetric efficiency and to therefore suit the needs of any particular application. This is a significant advantage vs. the fixed diameter, long pathway, circuitous designs that are

typical in conventional magnetically driven pumps. Thus, a wider application base is afforded by applying the invention.

[0032] A preferred embodiment of the invention has been described in considerable detail. Many modifications and variations to the embodiment described will be within the scope of the invention and apparent to those skilled in the art. Therefore, the invention should not be limited to the embodiment described, but should be defined by the claims which follow.